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Estimating the Determinants of Finnish Inflation*

Abstract

This paper estimates the determinants of Finnish quarterly inflation. Empirical long-run relations, consistent with different inflation theories, are estimated using the cointegrated VAR model for I(2) data. The relative importance of the theories are evaluated based on their statistical relevance in the Finnish inflation process. The primary determinant of Finnish inflation is product market excess demand. Other explanations such as money demand, imported inflation, and mark-up pricing are of minor importance. I also find evidence of an IS relationship determining real output and short-term interest rates. The long-term interest rates are adjusting to ensure that uncovered interest parity approximately holds.

JEL Classification: C32, C52, E31.

Keywords: Inflation, cointegration, I(2) processes, vector auto-regressive model.

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1 Introduction

Inflation is widely regarded as one of the most important macro economic indicators and is a major focus of economic policy. Yet, no single consensus theory of inflation has emerged. Moreover, the evidence from inflation studies, such as Hendry (2001), commonly suggests that the causes of inflation are many and varied. By contrast, theory models typically focus on a single or a few aspects of the inflation process. Surrey (1989) divides the theories of inflation into three categories. (i) *pure monetarist theories*, that attribute inflation to expansions in the money supply, in excess of the productive potential. (ii) *internal theories* whereby inflation arises through excess demand for goods and labor. (iii) *external theories* where inflation is imported, either directly through the price of foreign goods in the domestic consumption basket, or indirectly, through exchange rate movements. It is apparent that these theories are interlinked. For instance, the currently popular new Keynesian model (NKM) is a modern variant of the traditional Phillips curve framework, essentially providing a goods market excess demand explanation of inflation. However, it also contains monetary elements and, in recent open economy versions, external elements as well. Another theory is provided by the imperfect competition model (ICM), discussed in Kolsrud and Nymoen (1998), which views inflation as reconciling different real wage claims under product and labor market imperfections.

Different inflation theories can have different predictions or policy implications, and are not easily reconciled. Hence, there is a need to assess the relative importance of the different models empirically within a general framework. However, the obvious empirical difficulty in conducting such assessments is the large number of variables involved. This problem can be circumvented by dividing a general information set, that encompasses the different theories, into smaller subsets corresponding to particular theories. The smaller sets are subsequently analyzed separately and the results are used to reduce the general problem. This approach was originally taken by Surrey, who compared a commodity price model of inflation with a monetarist model of inflation on U.S. and U.K. data, and found that the commodity price model was superior. Surrey's approach was generalized by Juselius, K. (1992) to allow for non-stationary data. She analyzed Danish inflation and found that external factors were among the most important determinants, although several other factors mattered as well. More recent studies include Metin (1995) on Turkish data and Hendry (2001) on U.K. data. Metin found that fiscal

expansions dominated the determination of Turkish inflation, while Hendry found several causes of U.K. inflation. Particular to the latter studies, starting from Juselius, K. (1992), is that inflation is modelled through long-run feedback relations given by the different theories.

This paper evaluates the relative importance of different theories on the Finnish inflation process, using quarterly data. The data contains observations on a large number of potentially relevant variables over the estimation sample 1982:1-2006:1. Following the approach pioneered by Surrey and Juselius, K., the data is initially divided into smaller sets from which long-run feedback relations are obtained, using the cointegrated vector auto-regressive (VAR) model. The long-run feedback relations are then used to estimate the inflation process within a complete model. The theories are evaluated based on the statistical relevance of their corresponding feedback relations.

Previous studies on Finnish inflation are surprisingly scarce. The most closely related Finnish study is provided by Muhleisen (1995) who assessed the role of several leading indicators of Finnish inflation for the purpose of conducting monetary policy. He was primarily concerned with the forecast performance of the indicators rather than with evaluating different theory models. He found that a monetary conditions index, stumpage prices, and the effective exchange rate were among the strongest indicators. Also, in a remotely related study, Junttila (2001) tested an augmented Fisher hypothesis, taking open economy considerations into account. He obtained favorable results for the augmented Fisher hypothesis.

The study differs from the previous ones in at least three respects. First, I provide new evidence on the determinants of Finnish inflation. To the best of my knowledge, this is the first study to estimate the relative importance of different inflation theories on Finnish data. The main finding is that inflation is primarily determined by excess demand in the product market. Other explanations, such as mark-up pricing, money demand, and external theories are not very important. Second, I allow the data to be integrated of the second order which enables me to test the validity of nominal to real transformations¹. I find that Finnish nominal variables are best described as $I(2)$ processes. Moreover, nominal to real transformations are typically not rejected. Third, although the primary focus is on inflation, estimates of the processes that determine the other endogenous variables are obtained as well. I find evidence of an IS relationship in the data, which simultaneously

¹The cointegrated VAR model for $I(2)$ data is discussed by Johansen (1995, 1997).

determines both real output and the short-term interest rates. Furthermore, the long-term interest rates are adjusting to an approximate UIP condition.

Next section introduces the different theoretical models that are used to derive the corresponding empirical feedback relations. The statistical model is presented in section 3 and section 4 introduces the data (see also appendix A). The long-run relations of the partial systems are estimated in section 5 and the complete system is estimated in section 6. The results are also discussed in relation to the previous studies. Section 7 concludes.

2 Theoretical feedback relations

This sections discusses different theories of inflation and derives corresponding long-run feedback relations that can be used in the empirical analysis. The theories are divided into, excess demand and monetary theories, labor market theories, and external theories, in loose accordance with Surrey's categorisation. The new Keynesian model (NKM) is taken to be representative of goods market excess demand and monetary theories. The NKM is currently a popular choice for modelling inflation, and has a similar structure to more traditional excess demand and monetary theories of inflation². Furthermore, the standard version of the NKM have many desirable features, such as sticky prices and monopolistic competition in the goods market. Labor market theories of inflation are represented by the dynamic version of the imperfect competition model (ICM) derived by Kolsrud and Nymoen (1998). This model is representative of a class of models that emphasize the importance of imperfect competition and wage bargaining on the inflation process³. Pass-through effects are usually modelled within the afore mentioned theories, as in Monacelli (2005), or through international parity conditions (see for instance Rogoff (1996)).

A major difference between different inflation models lay in the way expectations enter into the model. For instance the new Keynesian framework predominately focuses on rational expectations, while the dynamic ICM model of Kolsrud and Nymoen (1998) assume that expectations are adaptive. Reconciling different expectation hypotheses is a major challenge to

²Detailed derivations of the NKM can be found in Clarida et al. (1999) and Walsh (2003), among others. A critical discussion from a historical point of view is provided by Rudd and Whelan (2005).

³See for instance Nickell (1990).

empirical modelling. However, there may be an easy way to overcome this difficulty. Both adaptive and rational expectations imply certain precise necessary conditions on a VAR model, provided that they are formed linearly. In particular, when data is non-stationary, the conditions can be given in terms of cointegration relations. These cointegration relations will in general have the same form as the economic long-run relations, as shown by Campbell and Shiller (1987) and Johansen and Swensen (1999). Hence, investigating necessary conditions provides a way of distinguishing between different theories, regardless of how expectations are formed. Accordingly, the implied necessary conditions of the theories are derived below.

2.1 Monetary theories and excess demand in the goods market

The new Keynesian model captures inflationary pressures from both excess demand in the goods market and monetary policy. The “core” of the model consist of two equations

$$y_t = \zeta_{11}E_t y_{t+1} - \zeta_{12}(i_t^s - E_t \Delta p_{t+1}^c) + \zeta_{13}y_{t-1} \quad (1)$$

$$\Delta p_t^c = \zeta_{21}E_t \Delta p_{t+1}^c + \zeta_{22}x_t + \zeta_{23}\Delta p_{t-1}^c \quad (2)$$

where y_t is real output, i_t^s is a short-term nominal interest rate, p_t^c is consumer prices, x_t is real marginal costs, and E_t is the expectations operator conditional on the agents information set at time t . The ζ_{ij} are used to distinguish the theory coefficients from the coefficients of the empirical feedback relations, φ_{ij} . Both $\zeta_{ij} \geq 0$ and $\varphi_{ij} \geq 0$ for all i and j in this section. The first equation is an optimizing IS curve, that relates output negatively to the real interest rate. The second equation is the new Keynesian Phillips curve (NKPC) that relates inflation positively to marginal costs. Real marginal costs are not observable in practice. However, they are proportional to the output gap, $x_t = h(y_t - y_t^n)$, under certain conditions, which can be used as a proxy.

Juselius (2006) shows that the expectational equations (1) and (2) imply necessary conditions on cointegration of the following form

$$y_t + \varphi_{10} + \varphi_{11}(i_t^s - \Delta p_t^c) = \varepsilon_{1t} \quad (3)$$

$$\Delta p_t^c + \varphi_{20} - \varphi_{21}(y_t - y_t^n) = \varepsilon_{2t} \quad (4)$$

where $\varepsilon_{it} \sim I(0)$. In addition, an optimal policy rule for the short-term interest rates is derived under discretion or commitment. Such rules are usually of the form

$$i_t^s + \varphi_{30} - \varphi_{31}(\Delta p_t^c - \Delta \bar{p}_t) - \varphi_{32}(y_t - y_t^n) = \varepsilon_{3t} \quad (5)$$

where \bar{p}_t is the target rate of inflation. Once, the interest rate rule is specified, money will be determined by

$$m_t - p_t^c + \varphi_{40} - \varphi_{41}y_t + \varphi_{42}i_t^s = \varepsilon_{4t} \quad (6)$$

where m_t is a nominal monetary aggregate. Thus, the NKM contains a money demand equation of the traditional form. However, in contrast with monetary theories of inflation, such as the P^* model of Hallman et al. (1991), it predicts that money is redundant in the inflation process.

Equations (3)-(6) provide the feedback relations that will be used to evaluate the goods market excess demand and monetarist theories of inflation.

2.2 Labor market theories of inflation

The dynamic ICM, derived by Kolsrud and Nymoen (1998) and extended by Bardsen et al. (2003), models inflation as reconciling different real wage claims in a setting where there are both product and labor market imperfections. Following Bardsen et al., firms set prices as a stationary mark-up over unit labor costs

$$p_t^p - w_t - \tau_t^w + a_t^l = \varepsilon_{5t} \quad (7)$$

where p_t^p is producer prices, w_t is the nominal wage rate, τ_t^w is a payroll tax, and a_t^l is labor productivity. The pricing equation (7) reflects a modern modelling approach, roughly consistent with the NKPC, when labor's share is used as a measure of marginal costs (see Galí and Gertler (1999)). It is also consistent with the price block of the Area Wide Model, described in Fagan et al. (2001). This equation can be rewritten in terms of consumer wages as

$$(w - p^c)_t + (p^c - p^p)_t + \tau^w - a_t^l = \varepsilon_{5t}.$$

The relationship between consumer and producer prices is given by

$$p_t^c = (1 - \zeta_{31})p_t^p + \zeta_{31}p_t^i + \zeta_{32}\tau_t^c, \quad 0 \leq \zeta_{31}, \zeta_{32} \leq 1$$

where p_t^i is the domestic currency price of imports and τ_t^c is indirect taxes.

The real wage rate is assumed to be determined through bargaining between labor unions and employers. The long-run wage equation reflects the utility functions of the bargainers relative to their bargaining power and has the form

$$w_t - p_t^c - \zeta_3(p_t^c - p_t^p) - \zeta_4 a_t^l + \zeta_5 u_t - \zeta_6 \tau_t^w = \varepsilon_{6t}$$

where u_t is the unemployment rate.

Bardsen et al. (2003), assume that the all variables are at most $I(1)$. However, this is at odds with the statistical properties of the Finnish data, where the nominal variables are typically found to be $I(2)$ ⁴. Thus, the framework must be modified to account for this possibility. Assuming that nominal to real transformations are $CI(2, 1)$, all that is needed are terms for nominal growth as well. If $w_t - p_t^c \sim I(1)$ and $w - p_t^p \sim I(1)$, then all nominal variables are pairwise cointegrated and share the same $I(2)$ trend. Thus, any of Δp_t^c , Δw_t , or Δp_t^p will be sufficient in a polynomial cointegrating relation. Since, the focus here is on inflation, Δp_t^c is chosen. Combining these results and adding the polynomial term yields

$$(w - p^c)_t + (p^c - p^p)_t + \tau^w - a_t^l - \varphi_{51} \Delta p_t = \varepsilon_{5t} \quad (8)$$

$$(w - p^c)_t - \varphi_{61}(p_t^c - p_t^p) - \varphi_{62} a_t^l + \varphi_{63} u_t - \varphi_{64} \tau_t^w - \varphi_{65} \Delta p_t = \varepsilon_{6t} \quad (9)$$

which provide the feedback relations of the ICM.

Inflation dynamics have traditionally been modelled relative to excess unemployment, i.e. in equations of the form

$$\Delta p_t + \varphi_{71}(u_t - u_t^n) = \varepsilon_{7t} \quad (10)$$

where u_t^n is the natural rate of unemployment. The natural rate of unemployment has usually been treated as a constant. However, this assumption is not very realistic and recent papers have attempted to endogenize the natural rate. Following Ball and Mankiw (2002), the natural rate is treated as a negative function of labor productivity

$$u_t^n = \zeta_7 - \zeta_8 a_t^l. \quad (11)$$

The rationale of (11), is that a shift in the relative size of different worker types, may lead to a more employable workforce from the perspective of the

⁴See Muhleisen (1995) and section 5 of this paper.

firms, and thus reduce the natural rate of unemployment. Combing (10) with (11) results in

$$\Delta p_t^c + \varphi_{70} + \varphi_{71}u_t + \varphi_{72}a_t^l = \varepsilon_{7t} \quad (12)$$

where $\varphi_{72} = 0$ corresponds to the constant natural rate case. Equation (12) provides a traditional Phillips curve feedback relation.

2.3 External theories

External inflation pass-through is modelled through the real exchange rate and the uncovered interest parity (UIP). If both purchasing power parity (PPP) and UIP hold, then

$$p_t^c - e_t - p_t^f = \varepsilon_{7t} \quad (13)$$

$$i_t - i_t^f - E_t\{\Delta e_{t+1}\} = \varepsilon_{8t} \quad (14)$$

where e_t is the nominal exchange rate and i^f is the foreign interest rate. The Johansen and Swensen (1999) method, using the PPP condition $E_t e_{t+1} = E_t(p_{t+1}^c - p_{t+1}^f)$ in (14), implies the that the following necessary condition on cointegration must hold

$$i_t - i_t^f + e_t + p_t^f - p_t^c = \varepsilon_{9t}.$$

However, both (13) and (14) may be too strict. If we allow agents to be conservative in incorporating expected changes in the exchange rate ⁵, the UIP can be expressed as

$$i_t - i_t^f - \varphi_{91}E_t\{\Delta e_{t+1}\} = \varepsilon_{9t}. \quad 0 < \varphi_{91} \leq 1$$

In this case the necessary condition is

$$(i - i^f)_t - \varphi_{91}(p^c - e - p^f)_t - \varphi_{92}\Delta p_t^c = \varepsilon_{9t} \quad (15)$$

where inflation has been added to allow for polynomial cointegration. Equation (15) together with the PPP condition will form the basis for estimating the foreign effects on inflation.

⁵Juselius, K. (1995) uses a similar assumption.

3 The cointegrated VAR model

This section introduces the cointegrated VAR model for $I(2)$ data. Detailed discussions of the model are provided by Johansen (1995, 1997). The p -dimensional VAR model with k lags can be written as

$$X_t = \sum_{i=1}^k A_i X_{t-i} + \Phi D_t + \varepsilon_t \quad (16)$$

where X_t is a p -dimensional vector of endogenous variables, D_t is a $p \times d$ matrix that collects the deterministic terms, and $\varepsilon_t \sim N_p(0, \Omega)$ is an *i.i.d.* disturbance. Equation (16) can be rewritten in error correction form

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Phi D_t + \varepsilon_t \quad (17)$$

where the parameter matrices are functions of the A_i . The process is $I(0)$ if the matrix Π is of full rank, while the process is non-stationary and not cointegrated if the rank of Π is zero. If, on the other hand, the matrix is of reduced rank $0 < r < p$ it can be decomposed into

$$\Pi = \alpha \beta' \quad (18)$$

where the two $p \times r$ matrices α and β are of full column rank. Let z_\perp denote the orthogonal complement of a matrix z . For future use define $\bar{z} = z(z'z)^{-1}$ and $\Gamma = I - \sum_{i=1}^{k-1} \Gamma_i$. If it further holds, that the $(p-r) \times (p-r)$ matrix $\alpha'_\perp \Gamma \beta_\perp$ is of full rank, then the process X_t is $I(1)$.

General linear hypotheses on β can be tested in the form

$$H_\beta : \beta = (H_1 \zeta_1, \dots, H_r \zeta_r) \quad (19)$$

where $H_i(p \times (p - m_i))$ imposes m_i ($0 \leq m_i \leq p - 1$) restrictions on β_i , and $\zeta_i((p - m_i) \times 1)$ consists of $p - m_i$ freely varying parameters. The likelihood ratio test of the hypothesis is asymptotically χ^2 distributed. Moreover, weak exogeneity can be tested as zero restrictions on the α matrix.

The $I(2)$ model is slightly more complicated and some additional notation is needed. Define $\beta_1 = \bar{\beta}_\perp \eta$, $\alpha_1 = \bar{\alpha}_\perp \xi$, $\beta_2 = \beta_\perp \eta_\perp$, and $\alpha_2 = \alpha_\perp \xi_\perp$. If $\alpha'_\perp \Gamma \beta_\perp$ is of reduced rank and $\bar{\alpha}'_2 \Theta \bar{\beta}_2$ has full rank, where Θ is a complicated

function of the parameters (provided by Johansen (1997)), then the process is integrated of order two. The $I(2)$ model is defined by the conditions

$$\begin{aligned}\Pi &= \alpha\beta' \\ \alpha'_\perp \Gamma \beta_\perp &= \xi\eta'\end{aligned}\tag{20}$$

where ξ and η are two $(p-r) \times s_1$, and $s_1 \leq p-r$ is the number of $I(1)$ trends. Denoting this model by $H(r, s_1, s_2)$, where $s_2 = p-r-s_1$ is the number of $I(2)$ trends, it can be shown

$$H(r, 0, p-r) \subset H(r, 1, p-r-1) \subset \dots \subset H(r, p-r, 0) = H_0(r) \subset H(r)$$

where $H_0(r)$ is the special case of the $I(1)$ model. This suggests that the natural sequence of simultaneously testing the rank and the number of $I(2)$ trends is by starting with $r=0$ and going from $s_1=0$ to $s_1=p$, then successively increasing rank by one and repeating until the first non-rejection occurs. The LR tests for this hypothesis is provided by Johansen (1997).

Equation (16) can be rewritten in second differences similar to (17) in order to accommodate the $I(2)$ process. However, a slightly different parametrization it turns out to be convenient and is given by

$$\Delta^2 X_t = \alpha(\rho'\tau'X_{t-1} + \psi'\Delta X_{t-1}) + \omega'\tau'\Delta X_{t-1} + \sum_{i=1}^{k-2} \Psi_i \Delta^2 X_{t-i} + \Phi D_t + \varepsilon_t \tag{21}$$

where $\rho = (I, 0)'$, $\tau = (\beta, \beta_1)$, and ψ and ω are complicated expressions of the parameters. The term in the parenthesis collects the polynomially cointegrating relations and $\omega'\tau'\Delta X_{t-1}$ defines $r+s_1$ relations that need to be differenced in order to become stationary. Given that the conditions in (20) are satisfied, the moving average representation of the process is given by

$$X_t = C_2 \sum_{i=1}^t \sum_{s=1}^i \varepsilon_s + C_1 \sum_{i=1}^t \varepsilon_i + C^*(L)\varepsilon_t + A + Bt \tag{22}$$

where $C_2 = \beta_2(\alpha_2\Theta\beta_2)^{-1}\alpha'_2$, $\beta'C_1 = \bar{\alpha}'\Gamma C_2$, $\beta'_1 C_1 = \bar{\alpha}'_1(I_p - \Theta C_2)$, $C^*(L)\varepsilon_t$ collects the stationary part of the process, and A and B are suitably restricted in order to avoid quadratic or cubic trends in the model⁶. It can be seen from (22) that α_2 can be interpreted as the composition of the $I(2)$ trends, while $\beta_2(\alpha_2\Theta\beta_2)^{-1}$ gives the corresponding loadings.

⁶These restrictions are derived in Rahbek et al. (1999) and are used throughout.

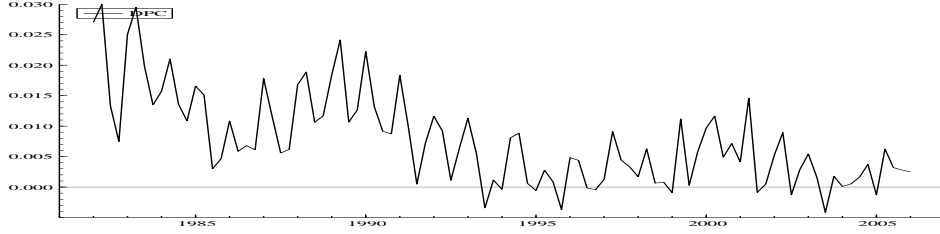


Figure 1: Quarterly Finnish consumer price inflation over the sample 1982:1-2006:1.

Finally, m restrictions on τ can be tested by expressing the hypothesis

$$\mathcal{H}_\tau : \tau = H\zeta \quad (23)$$

where H is a $p \times (p - m)$ design matrix and ζ is a $(p - m) \times (r + s_1)$ matrix of freely varying parameters. The test is described by Johansen (2006) and is asymptotically $\chi^2((r + s_1)m)$ distributed, and is suitable for testing nominal to real transformations.

4 Data and information sets

This section introduces the data and divides it into three information sets, corresponding to the theoretical division of section 2. Product market excess demand and monetary theories of inflation are modelled using the information set $\mathcal{I}_1 = \{p^c, y, y^n, m, i^s\}$, where p^c is (the log of) consumer prices, y is (the log of) nominal GDP, y^n is (the log of) potential output, m is (the log of) the monetary aggregate M3, and i^s is the short-term interest. The sample consist of quarterly observations over the period 1982:1-2006:1. Consumer price inflation is depicted in figure 1. Alternatively, the implicit price deflator could be used instead. However, two measures are very similar and cointegrated, so it does not matter which one is used.

Labor market theories of inflation are modelled by the information set $\mathcal{I}_2 = \{p^c, p^p, w, a^l, u, \tau^c, \tau^w\}$, where p^p is (the log of) producer prices, w is (the log of) a nominal wage index, a^l is (the log of) a measure of labor productivity, u is the unemployment rate, τ^c is (the log of) the ratio of indirect taxes to consumption, and τ^w is (the log of) the ratio of taxes on wages to total wages and salaries.

The foreign sector is modelled by the information set $\mathcal{I}_3 = \{p^c, p^f, e, i^l, i^f\}$, where p^f is (the log of) foreign trade weighted consumer prices, e_t is (the log of) nominal trade weighted exchange rate, i^l is the yield of 10 years government bonds, and i^f is the EU equivalent.

A detailed description of the data is provided in appendix A. For latter use the spread between consumer and producer prices and the spread between domestic and foreign prices are defined by $\pi_t^d = p_t^c - p_t^p$ and $\pi_t^f = p_t^c - p_t^f$, respectively. The real exchange rate is defined by the restriction $q_t = \pi_t^f + e_t$ ⁷, and any real transformation of a nominal variable x_t^n is denoted $x_t^r = x_t^n - p_t^c$.

5 Long-run relationships

The information sets, corresponding to the different inflation theories, are modelled in this section. The objective is to obtain data consistent empirical long-run relations that correspond closely to the theoretical feedback relations of section 2.

5.1 Excess demand in the goods market and monetary theories

Equation (21) was estimated with $X_t = (p_t^c, m_t, y_t, y_t^n, i_t^s)'$, a suitably restricted trend, and four transitory shock dummies $D89$, $D91$, $D92a$, and $D92b$ (described appendix A). At the outset, p_t^c , m_t , y_t , and y_t^n potentially contain $I(2)$ trends, while the nominal short run interest rate is at most $I(1)$ *a priori*. The $I(2)$ reduced rank test is reported in table 1. It can be seen from the table that the appropriate choices of rank and $I(2)$ trends should be $r = 2$ and $s_2 = 2$ (implying $s_1 = 1$, i.e. one $I(1)$ trend). This result is puzzling from an economic point of view. Since there is only one nominal price index, it would suggest at least one violation of nominal to real transformations. However, there is another potential explanation of this outcome. It is apparent that there is an potential level shift in the series around 1992 in the short-term interest rate series (see figure 2). This shift might create the illusion of an additional $I(2)$ trend in the data.

The timing of the shift matches the abandonment of the policy of the 'strong markka', whereby Finland held a semi fixed exchange rate, and the

⁷The positive sign on e_t is due to the empirical definition of the nominal effective exchange rate. See sources and methods of OECD economic outlook.

$I(2)$ rank test statistic, $X_t = (p_t^c, y_t, y_t^n, m_t, i_t)'$.						
r/s_2	5	4	3	2	1	0
0	417.24 (0.00)	328.04 (0.00)	261.72 (0.00)	211.11 (0.00)	176.30 (0.00)	160.17 (0.00)
1		239.79 (0.00)	178.14 (0.00)	128.12 (0.00)	105.53 (0.00)	91.68 (0.00)
2			104.60 (0.00)	60.80 (0.22)	45.86 (0.23)	43.80 (0.04)
3				26.01 (0.93)	12.73 (0.99)	9.69 (0.93)
4					8.42 (0.80)	1.61 (0.98)

Table 1: The $I(2)$ rank test statistic for the excess demand and monetary sector. The test sequence begins from $r = 0$, $s_2 = 5$ (upper left corner), and proceeds by sequentially moving from left to right. If all elements of a row are rejected, the rank is increased by one. The procedure is repeated until the first non-rejection.

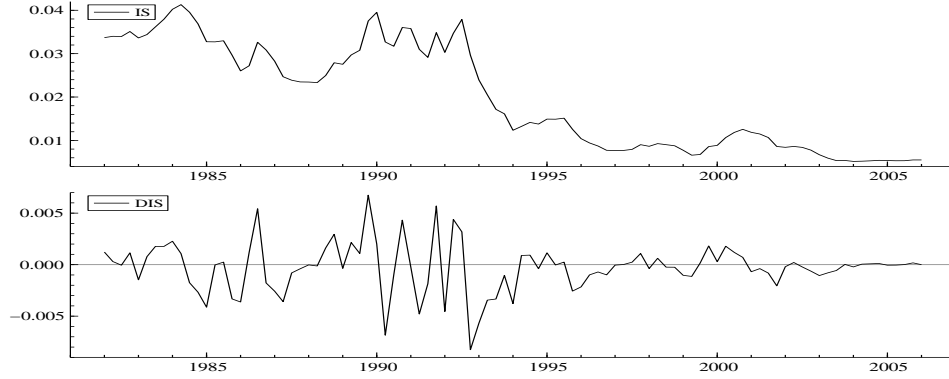


Figure 2: Finnish short-term interest rates and its first difference. The volatile period in the beginning of the 1990's, and the level shift in 1992, causes a near $I(2)$ trend in the data.

The $\hat{\alpha}_2$ and $\hat{\alpha}_1$ matrices.					
	$\Delta^2 p_t^c$	$\Delta^2 y_t$	$\Delta^2 y_t^n$	$\Delta^2 m_t$	$\Delta^2 i_t$
$\hat{\alpha}'_{21}$	0	-0.03 (-1.81)	-0.02 (2.10)	-0.01 (-0.42)	1
$\hat{\alpha}'_{22}$	1	0.02 (0.38)	0.17 (6.04)	-0.03 (-0.33)	0
$\hat{\alpha}'_{11}$	0.07 (1.43)	0.06 (0.31)	-0.54 (-5.93)	-0.56 (-1.97)	-0.01 (-0.92)

Table 2: The $\hat{\alpha}_2$ and $\hat{\alpha}_1$ matrices of the excess demand and monetary sector. The vectors of $\hat{\alpha}_2$ are normalized on the most significant variables.

adoption of a floating exchange rate. Furthermore, the series displays increasingly volatile behaviour in the few years preceding the policy change. Presumably, much of this variation can be attributed to the speculative attacks on the currency in the wake of the crisis in the beginning of the 90's and to the devaluation in 1991 (see Honkapohja and Koskela (1999)). The dummy variables $D89$, $D91$, $D92a$, and $D92b$ capture these events. However, it turns out that the level shift is difficult to model deterministically, and is more likely to be stochastic by nature⁸.

If the cause of the additional $I(2)$ trend can be found in the short-term interest rate series, it should turn up as a unit vector in $\Delta^2 i_t$ in the $\hat{\alpha}_2$ matrix. Table 2 reports the orthogonal alpha matrices, $\hat{\alpha}_1$ and $\hat{\alpha}_2$. The table shows that the first vector, $\hat{\alpha}_{21}$, of $\hat{\alpha}_2$ is (almost) a unit vector in the interest rate, while the second vector, $\hat{\alpha}_{22}$, consist of significant coefficients to both (the rates of change in) consumer prices and potential output. Hence, it seems plausible that the additional $I(2)$ trend is a consequence of the stochastic level shift in the interest rates series. Furthermore, neglecting this additional $I(2)$ trend should not leave a very large root in the system. Choosing $r = 2$, $s_1 = 2$, and $s_2 = 1$, leaves a root of 0.73, in line with this prediction. The table also reveals that the composition of the real $I(1)$ trend, given by $\hat{\alpha}_1$, has a significant coefficient to potential output, which is very plausible from an economic point of view. We will continue to assume $r = 2$, $s_1 = 1$, and $s_2 = 2$, with the cautious interpretation that one of the $I(2)$ trends is a convenient approximation to an $I(1)$ series with a level shift. Similar

⁸Attempting to model the shift by a dummy variable, provides no improvement of the results below. The exclusion test for this shift dummy cannot be rejected at the 1% significance level.

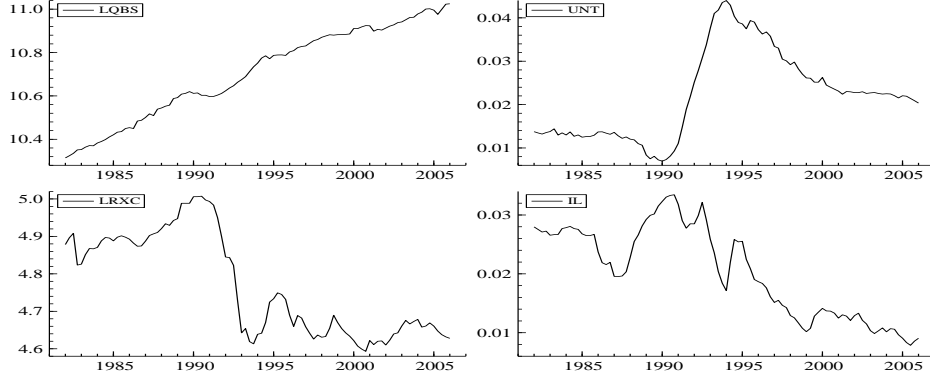


Figure 3: Finnish labor productivity (upper left), unemployment (upper right), real exchange rates (lower left), and long-term interest rates (lower right).

problems will turn up in sections 5.2 and 5.3 below, in particular in the labor productivity, unemployment, real exchange rate, and long-term interest rate series. These are depicted in figure 3.

Given the choices of rank and $I(2)$ trends, nominal to real transformations can be tested as a homogeneity restriction on τ . The hypothesis (23) is tested, with $m = 1$ and the design matrix

$$H' = \begin{pmatrix} 1 & -1 & 0 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 & 0 \\ 1 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}.$$

The LR test of the restriction produce a $\chi^2(3) = 7.89$ and a corresponding p-value of 0.05, i.e. the restrictions cannot be rejected. Consequently, it is possible to transform the data into real $I(1)$ variables without serious loss of information. In this case, Δp_t needs to be included in the model to allow for polynomial cointegration.

The nominal to real transformations allow us to use the $I(1)$ model. Thus, (17) was estimated with $X_t = (\Delta p_t^c, y_t^r, y_t^{rn}, m_t^r, i_t)^'$, a linear trend restricted in the cointegration space, and the four dummy variables included. This model has been analyzed extensively by Juselius (2006), and the results are only summarized here. The potential output, y_t^{rn} , is treated as weakly exoge-

Estimated α and β matrices.						
	Δp_t^c	y_t^r	y_t^{rn}	m_t^r	i_t	t
$\hat{\beta}'_1$	-1	0.03 (2.74)	0	0	1	0.00 (0.47)
$\hat{\beta}'_2$	1	-0.04 (-3.80)	0.04 (3.80)	0	0	0.00 (8.57)
	$\Delta^2 p_t^c$	Δy_t^r	Δm_t^r	Δi_t	—	—
$\hat{\alpha}'_1$	0.10 (1.09)	-1.20 (-6.13)	0.69 (1.14)	-0.10 (-3.06)	—	—
$\hat{\alpha}'_2$	-0.60 (-4.99)	-1.34 (-5.11)	-0.28 (-0.34)	-0.06 (-1.22)	—	—

Table 3: Estimated α and β matrices of the excess demand and monetary sector. The $\hat{\beta}$ vectors are normalized on variables that are error correcting.

nous. The rank is assumed to be two, in accordance with the findings in table 1. Juselius (2006) found two identified cointegration relations. The first is similar to the IS curve in equation (3), while the second can be interpreted as a Phillips curve relation (4), with a linear trend approximating some missing information⁹. The normalized and restricted estimates of the β and α vectors are reproduced in table 3. $\hat{\beta}'_1 X_t$ describes a negative relationship between output and the real rate of interest and can be interpreted as an IS curve. As is clear from the table, this relationship is error correcting in both short-run interest rates and real output¹⁰. The second cointegration relationship, $\hat{\beta}'_2 X_t$, describes a positive relation between inflation and the output gap and can be interpreted as a Phillips curve augmented by a linear trend.

The partial system was also checked for misspecification, and parameter stability by the tests described in Dennis (2006). There were no significant misspecification tests, and the parameters of the long-run part of the model were constant.

⁹Graphical inspection of Finnish inflation reveals a small downward trend during the past 25 years, while the output gap cannot, by construction, contain such a trend. This trend can be approximated by a linear deterministic trend, as explained by Juselius (2006).

¹⁰A variable is error correcting a cointegrating vector contains the variable and enters the equation of the variable with a negative sign. For example, if $y - \beta'_x x$ is a cointegration vector and $\Delta y_t = -\alpha_y(y - \beta'_x x)_{t-1}$ then y is error correcting and $y - \beta'_x x$ is an error correction mechanism.

$I(2)$ rank test statistic, $X_t = (p_t^c, p_t^p, w_t, a_t^l, u_t, \tau_t^w)'$.							
r/s_2	6	5	4	3	2	1	0
0	578.01 (0.00)	418.04 (0.00)	321.58 (0.00)	258.80 (0.00)	235.83 (0.00)	216.86 (0.00)	201.14 (0.00)
1		314.61 (0.00)	240.93 (0.00)	179.17 (0.00)	154.16 (0.00)	135.95 (0.00)	128.19 (0.00)
2			169.99 (0.00)	121.86 (0.02)	94.14 (0.05)	80.85 (0.02)	77.09 (0.00)
3				86.40 (0.08)	55.03 (0.44)	39.06 (0.54)	35.46 (0.23)
4					36.67 (0.44)	20.29 (0.73)	14.57 (0.62)
5						11.67 (0.50)	3.29 (0.83)

Table 4: The $I(2)$ rank test statistic of the labor market sector. The test sequence begins from $r = 0$, $s_2 = 6$ (upper left corner), and proceeds by sequentially moving from left to right. If all elements of a row are rejected, the rank is increased by one. The procedure is repeated until the first non-rejection.

5.2 Labor market theories

Equation (21) was estimated with $X_t = (p_t^c, p_t^p, w_t, a_t^l, u_t, \tau_t^w)'$, and a restricted trend in the cointegration space¹¹. Initial testing revealed no significant misspecification tests. Table 4 reports the $I(2)$ rank test statistic. As can be seen from the table, the rank should be three with possibly two, or even three three, $I(2)$ trends¹². Since there are only three nominal variables, that potentially are are $I(2)$, similar problems as in section 5.1 may be present. Indeed, both the unemployment series and to some extent the productivity series display level shifts (see figure 3). Table 5 reports the orthogonal $\hat{\alpha}_1$ and $\hat{\alpha}_2$ matrices. It can be seen from the table that the first $I(2)$ trend is composed of twice accumulated unemployment shocks, in line with the suspicion. The second $I(2)$ trend is composed of twice accumulated shocks to producer and consumer prices. Thus, if the results are interpreted in a similar fashion as in section 5.1, there is one nominal $I(2)$ trend related

¹¹Indirect taxes, τ^c , was initially included in the analysis, but long-run exclusion could not be rejected in the series. Retaining this variable from the system does not alter the results significantly.

¹²Sensitivity analysis with respect to the cases $r = 2$, $s_2 = 2$, and $r = 3$, $s_2 = 3$ were conducted and the results were almost similar. The results are available upon request.

The $\hat{\alpha}_2$ and $\hat{\alpha}_1$ matrices.						
	$\Delta^2 p_t^c$	$\Delta^2 p_t^p$	$\Delta^2 w_t$	$\Delta^2 a_t^l$	$\Delta^2 u_t$	$\Delta^2 \tau_t^w$
$\hat{\alpha}'_{21}$	0.03 (0.35)	0	0.03 (0.13)	-0.09 (-0.56)	1	0.00 (0.08)
$\hat{\alpha}'_{22}$	-0.22 (-4.58)	1	0.00 (0.03)	0.10 (1.27)	0	0.01 (1.67)
$\hat{\alpha}'_{11}$	0.30 (11.92)	0.07 (1.02)	-0.20 (-2.87)	-0.06 (-1.41)	-0.01 (-0.69)	0.01 (2.39)

Table 5: The $\hat{\alpha}_2$ and $\hat{\alpha}_1$ matrices of the labor market sector. The vectors of $\hat{\alpha}_2$ are normalized on the most significant variables.

to producer and consumer prices, one $I(1)$ trend related to unemployment, which is approximated by an $I(2)$ trend in order to account for a stochastic shift in the series. There is also an additional $I(1)$ trend related to consumer prices and wages.

Imposing $r = 2$, $s_1 = 1$, and $s_2 = 2$, homogeneity between prices and wages can be tested on τ by (23) and the following design matrix

$$H' = \begin{pmatrix} 1 & -1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}.$$

The LR test produces a $\chi^2(4)$ value of 13.61 and a corresponding p-value of 0.01. The hypothesis cannot be rejected on a 1% significance level, although it would be rejected on a 5% significance level. Imposing homogeneity at this stage simplifies the analysis, although, a small part of the $I(2)$ trend may be left in the data. The transformations $p_t^c - p_t^p = \pi_t^d$ and $w_t - p_t^c = w_t^r$ are, thus, imposed and Δp_t^c is included in the model to allow for polynomial cointegration.

The $I(1)$ model (17) with $X_t = (\Delta p_t^c, w_t^r, a_t^l, u_t, \pi_t^d, \tau_t^w)'$ and a linear trend in the cointegration space was estimated. The rank was assumed to be tree, in line with the results in table 4. Long-run exclusion and stationarity were rejected in all the variables, while π_t^d was found to be weakly exogenous ($\chi^2(3) = 7.19$ and corresponding p-value of 0.07). Hence, a partial model with π_t^d treated as weakly exogenous was subsequently estimated.

Tests of $\beta_{\mathcal{H}_i} \in sp(\hat{\beta})$ or equivalently $\beta_{\mathcal{H}_i}' X^* \sim I(0), X_t^* = (\Delta p_t, w_t^r, a_t^l, u_t, \pi_t^d, \tau_t^w, t)'$	
	p-value
$\beta_{\mathcal{H}_1}^* = (-\varphi_{51}, 1, -1, 0, 1, 1, 0)' \in sp(\hat{\beta})$	0.00
$\beta_{\mathcal{H}_2}^* = (-\varphi_{51}, 1, -1, 0, 0, 0, 0)' \in sp(\hat{\beta})$	0.37
$\beta_{\mathcal{H}_3}^* = (0, 1, -1, \varphi_{63}, 0, \varphi_{64}, 0)' \in sp(\hat{\beta})$	0.68
$\beta_{\mathcal{H}_4}^* = (1, 0, 0, \varphi_{71}, 0, 0, 0)' \in sp(\hat{\beta})$	0.00
$\beta_{\mathcal{H}_5}^* = (1, 0, \varphi_{72}, \varphi_{71}, 0, 0, 0)' \in sp(\hat{\beta})$	0.88
$\beta_{\mathcal{H}_6}^* = (0, 0, \varphi_a, 1, -\varphi_\pi, \varphi_\tau, -\varphi_t)' \in sp(\hat{\beta})$	–

Table 6: The tests of various hypotheses on the cointegration space of the labor market model. φ_x in the last hypothesis is the coefficient corresponding to variable x .

Different hypotheses corresponding to the feedback relations in section 2.2 were tested on the cointegration space. The results are reported in table 6. The first hypothesis, $\beta_{\mathcal{H}_1}^*$, corresponds to testing if the mark-up pricing relation (8) is stationary. The hypothesis is rejected due to insignificant coefficients on the price wedge, π_t^d , and the payroll tax, τ_t^w . Retaining these from the relation leads to the second hypothesis, $\beta_{\mathcal{H}_2}^*$. The hypothesis cannot be rejected, with a p-value of 0.37. Interestingly, this relation has a fairly close correspondence to the necessary condition implied by the NKPC, when labor's share is used as a measure of marginal cost (see Juselius (2006)). The relation in $\beta_{\mathcal{H}_3}^*$ corresponds to the wage equation (9), where $\varphi_{61} = 0$ and $\varphi_{62} = 1$. This relation cannot be rejected (p-value 0.68). The hypothesis $\beta_{\mathcal{H}_4}^*$ tests the stationarity of a traditional Phillips curve where the natural rate of unemployment is treated as a constant (see equation (10)). The hypothesis is rejected. The next hypothesis, $\beta_{\mathcal{H}_5}^*$, tests the traditional Phillips curve with an endogenous natural rate given by equation (12). The hypothesis cannot be rejected, with a p-value of 0.88. The final relation in the table is just identifying and is, thus, not a testable hypothesis. It displays dynamics roughly consistent with a relation for determining unemployment.

The joint test of $(\beta_{\mathcal{H}_2}^*, \beta_{\mathcal{H}_3}^*, \beta_{\mathcal{H}_6}^*) = \hat{\beta}^*$ cannot be rejected, with $\chi^2(5) = 4.32$ and a corresponding p-value of 0.50. However, nor can $(\beta_{\mathcal{H}_3}^*, \beta_{\mathcal{H}_5}^*, \beta_{\mathcal{H}_6}^*) = \hat{\beta}^*$ be rejected, with $\chi^2(4) = 1.27$ and a corresponding p-value of 0.87. Hence, both of these rotations are acceptable representations of the cointegration

Estimated α and β matrices.							
	Δp_t^c	w_t	a_t^l	u_t	π_t^d	τ_t^w	t
$\hat{\beta}'_1$	1	-0.09 (-12.60)	0.09 (12.60)	0	0		0
$\hat{\beta}'_2$	0	1	-1	5.75 (15.81)	0.44 (11.92)	0	0
$\hat{\beta}'_3$	0	0	0.41 (4.21)	1	0.23 9.06	-0.33 (-5.25)	-0.003 (-5.00)
	$\Delta^2 p_t^c$	Δw_t	Δa_t^l	Δu_t	$\Delta \tau_t^w$		
$\hat{\alpha}'_1$	-0.72 (-6.12)	-0.55 (-2.20)	-0.55 (-1.92)	0.03 (1.11)	-0.56 (-0.12)	-	-
$\hat{\alpha}'_2$	-0.01 (-0.87)	-0.16 (-4.79)	0.07 (1.90)	0.01 (3.71)	-3.36 (-5.12)	-	-
$\hat{\alpha}'_3$	0.07 (2.62)	0.23 (4.06)	-0.12 (-1.81)	-0.03 (-4.66)	2.51 (2.27)	-	-

Table 7: Estimated α and β matrices of the labor market sector. The $\hat{\beta}$ vectors are normalized on variables that are error correcting.

space¹³. The first representation, $(\beta_{\mathcal{H}_2}^*, \beta_{\mathcal{H}_3}^*, \beta_{\mathcal{H}_6}^*) = \hat{\beta}^*$, will be used here and in section 6, due to the NKPC interpretation of the relation in $\beta_{\mathcal{H}_4}^*$ ¹⁴. The identified $\hat{\beta}$ with corresponding $\hat{\alpha}$ are reported in table 7.

As in the previous section, there were no significant misspecification tests. The first two $\hat{\beta}$ vectors displayed constant parameters over the period, while there were indications of a shift in the parameters of the third vector in the beginning of the 90's. Overall, the parameters of the system were reasonable stable.

5.3 External theories

Equation (21) was estimated with $X_t = (p_t^c, p_t^f, e_t, i_t^l, i_t^f)'$ and a restricted trend. Again, there were no significant misspecification tests apart from some small ARCH effects in the interest rate series. The $I(2)$ rank test statistic is reported in table 8. The table reveals that the rank should be two with two $I(2)$ trends ($s_2 = 3$ is also borderline accepted). An approximate

¹³ $(\beta_{\mathcal{H}_2}^*, \beta_{\mathcal{H}_3}^*, \beta_{\mathcal{H}_5}^*) = \hat{\beta}^*$ is rejected, with $\chi^2(7) = 18.51$ and a p-value of 0.01.

¹⁴The analysis in section 6 was also done using the second representation $(\beta_{\mathcal{H}_3}^*, \beta_{\mathcal{H}_5}^*, \beta_{\mathcal{H}_6}^*) = \hat{\beta}^*$. The results were remarkably similar, in particular with respect to inflation.

$I(2)$ rank test statistic, $X_t = (p_t^c, p_t^f, e_t, i_t^l, i_t^f)'$						
r/s_2	5	4	3	2	1	0
0	296.97 (0.00)	230.76 (0.00)	184.61 (0.00)	157.59 (0.00)	138.53 (0.00)	126.43 (0.00)
1		171.99 (0.00)	130.87 (0.00)	104.45 (0.01)	89.82 (0.00)	83.90 (0.00)
2			91.09 (0.03)	61.61 (0.19)	52.11 (0.07)	43.52 (0.04)
3				35.09 (0.53)	25.66 (0.38)	20.33 (0.21)
4					11.84 (0.48)	7.47 (0.31)

Table 8: The $I(2)$ rank test statistic of the external sector. The test sequence begins from $r = 0$, $s_2 = 5$ (upper left corner), and proceeds by sequentially moving from left to right. If all elements of a row are rejected, the rank is increased by one. The procedure is repeated until the first non-rejection.

level shift in the long-term interest rate series may be causing the extra $I(2)$ trend. Imposing $r = 2$, $s_1 = 1$ and $s_2 = 2$ on the model, table 9 reports the estimated α_2 and α_1 matrices. $\hat{\alpha}_{21}$ clearly indicates that the first $I(2)$ trend, to a large extent, consists of twice accumulated foreign price shocks. The second $I(2)$ trend consists of twice accumulated shocks to the long-term interest rates. Again, the suspicion that the level shift in the interest rate series may account for second $I(2)$ trend seems to be warranted. As before, we proceed by assuming $r = 2$, $s_1 = 1$ and $s_2 = 2$, where one of the $I(2)$ trends is a “true” nominal trend and the other is a convenient approximation for the stochastic level shift in the interest rate series. Table 9 also reveals

The $\hat{\alpha}_2$ and $\hat{\alpha}_1$ matrices.					
	$\Delta^2 p_t^c$	$\Delta^2 p_t^f$	$\Delta^2 e_t$	$\Delta^2 i_t^l$	$\Delta^2 i_t^f$
$\hat{\alpha}'_{21}$	0.68 (1.41)	1	0.45 (2.10)	0	0.24 (0.10)
$\hat{\alpha}'_{22}$	-0.14 (-1.12)	0	-0.06 (-1.17)	1	-0.04 (-0.04)
$\hat{\alpha}'_{11}$	0.03 (0.10)	0.04 (0.09)	0.02 (0.12)	-0.01 (-0.07)	-0.27 (-5.32)

Table 9: The $\hat{\alpha}_2$ and $\hat{\alpha}_1$ matrices of the external sector. The vectors of $\hat{\alpha}_2$ are normalized on the most significant variables.

that the single $I(1)$ trend consist of once cumulated shocks to the foreign long-term bond rate.

Testing homogeneity between p_t^c and p_t^f on τ produces a p-value of 0.27, and is hence not rejected. The restricted estimates reveal that the coefficient on the nominal exchange rate is also very close to one. Consequently, testing the real exchange rate restriction on τ , by the the following design matrix

$$H' = \begin{pmatrix} 1 & -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix},$$

produces a p-value of 0.18. Note that this hypothesis does not require that $e_t \sim I(2)$ or that $q_t = p_t^c - p_t^f + e_t \sim I(0)$. Thus, the data can be transformed from $I(2)$ to $I(1)$ using π_t^f since homogeneity was not rejected. As before, Δp_t^c is also added to the information set.

Model (17) was estimated with $X_t = (\Delta p_t^c, \pi_t^f, e_t, i_t^l, i_t^f)'$, and a linear trend restricted in the cointegration space. The rank was set in accordance with the previous findings. Not surprisingly, the restricted linear trend was found to be long-run excludable ($\chi^2(2) = 1.34$ with corresponding p-vale of 0.51), and the model was re-estimated with this modification. The nominal exchange rate and the foreign interest rates were found to be weakly exogenous, with p-values 0.04 and 0.38, respectively. None of the variables were found to be stationary or excludable and there were no significant misspecification in the model.

Various hypotheses, corresponding to the feedback relations in section 2.3, were tested on the cointegration space. The results are reported in Table 10. The first hypothesis in the table corresponds to testing the stationarity of the real exchange rate. The hypothesis is rejected, as should be expected given the past evidence on testing the PPP¹⁵. $\beta_{\mathcal{H}_2}$ tests the UIP (15), where the coefficient on the expected real exchange rate is allowed to vary. The hypothesis is rejected. The fourth relation $\beta_{\mathcal{H}_3}$ tests the UIP where the coefficient on the foreign interest rate is allowed to vary, as well. The hypothesis cannot be rejected, with a p-value of 0.62. The final relation in $\beta_{\mathcal{H}_4}$ is a, somewhat peculiar, relation between inflation and the long-term interest rate, where inflation is proportional to the interest rate with a coefficient of 0.5. The relation cannot be rejected.

¹⁵Rogoff (1996) provides a review of this literature.

Tests of $\beta_{\mathcal{H}_i} \in sp(\hat{\beta})$ or equivalently $\beta_{\mathcal{H}_i} X'_t \sim I(0)$, $X_t = (\Delta p_t^c, \pi_t^f, e_t, i_t^l, i_t^f)'$	
	p-value
$\beta_{\mathcal{H}_1} = (0, 1, 1, 0, 0)' \in sp(\hat{\beta})$	0.00
$\beta_{\mathcal{H}_2} = (0, -\varphi_{91}, -\varphi_{91}, 1, -1)' \in sp(\hat{\beta})$	0.00
$\beta_{\mathcal{H}_3} = (0, -\varphi_{91}, -\varphi_{91}, 1, -\varphi_{if})' \in sp(\hat{\beta})$	0.62
$\beta_{\mathcal{H}_4} = (1, 0, 0, -0.5, 0)' \in sp(\hat{\beta})$	0.29

Table 10: The tests of various hypotheses on the cointegration space of the external sector. φ_{if} in the last hypothesis is the coefficient on the foreign price relation.

Estimated α and β matrices.					
	Δp_t^c	π_t^f	e_t	i_t^l	i_t^f
$\hat{\beta}'_1$	1	0	0	-0.5	0
$\hat{\beta}'_2$	0	-0.03 (-6.16)	-0.03 (-6.16)	1	-0.64 (-8.23)
	$\Delta^2 p_t^c$	$\Delta \pi_t^f$	Δi_t^l	—	—
$\hat{\alpha}'_1$	-0.62 (-4.93)	-0.30 (-2.01)	0.02 (0.56)	—	—
$\hat{\alpha}'_2$	-0.68 (-3.85)	-1.23 (-5.96)	-0.15 (-3.76)	—	—

Table 11: Estimated α and β matrices of the external sector. The β vectors are normalized according to significant error correction terms.

Finally, the LR test of $(\beta_{\mathcal{H}_3}, \beta_{\mathcal{H}_4}) = \hat{\beta}$ produced a $\chi^2(4)$ value of 3.72 and a p-value of 0.45. The estimated system, along with the corresponding $\hat{\alpha}$ vectors are reported in table 11. Again, there were no significant misspecification tests, and the parameters of the system were constant over the period.

6 The complete system

This section combines the results from the partial systems above. The cointegration relations $\hat{\beta}'_1 X_t$ and $\hat{\beta}'_2 X_t$ from section 5.1, are labeled ecm_t^{is} and ecm_t^{pc} , where the superscripts denote the IS curve and the Phillips curve re-

spectively. $\hat{\beta}'_1 X_t$, $\hat{\beta}'_2 X_t$ and $\hat{\beta}'_3 X_t$ from section 5.2 are labeled ecm_t^{pmu} (price mark-up), ecm_t^{wc} (wage curve), and ecm_t^{ur} (unemployment relation), respectively. The relations from section 5.3 are labeled ecm_t^{ir} (inflation relation) and ecm_t^{uip} . Full information maximum likelihood (FIML) was used to estimate the complete system

$$\Delta X_{1,t} = B_1 \Delta X_{2,t} + B_2 \Delta X_{t-1} + \alpha_1 ECM_{t-1} + \Psi D_t + \varepsilon_t \quad (24)$$

where $X_{1,t} = (\Delta p_t^c, y_t^r, m_t^r, i_t^s, w_t^r, a_t^l, u_t, \tau_t^w, i_t^l, \pi_t^f)'$, $X_{2,t} = (y_t^{rn}, \pi_t^d, e_t, i_t^f)'$, $X_t = (X'_{1,t}, X'_{2,t})'$, ECM_t is a column vector that collects the seven error correction mechanisms, D_t contains a constant, three centered seasonal dummies, and $D89$, $D91$, $D92$, and $D92b$, B_1 is 10×4 , B_2 is 10×14 , α_1 is 10×7 and Ψ is 10×8 . It is clear that the system is highly over-parameterized. To cope with this problem the system was initially reduced by F-tests on retained regressors. By this approach, $\Delta^2 p_{t-1}^c$, Δm_{t-1}^r , $\Delta \tau_{t-1}^w$, $\Delta \pi_t^d$, $\Delta \pi_{t-1}^d$, Δe_t , Δe_{t-1} , and Δi_{t-1}^f could be retained from the system (p-values 0.77, 0.32, 0.09, 0.30, 0.36, 0.38, 0.35, and 0.37, respectively). The strange error correction mechanism, ecm_{t-1}^{ir} , could also be retained from the system (p-value 0.69)¹⁶.

After the initial reduction of redundant variables, zero restrictions were successively placed on insignificant variables in the individual equations of the system. Testing the reduced system for over-identifying restrictions produced $\chi^2(150) = 142.71$ and a corresponding p-value of 0.65. The parsimonious system is reported in table 12. There were no significant misspecification in the model apart from a rejection of normality in the long-term interest rate equation.

Before discussing the individual equations, it is worth noting that equation 2, describing the change in real output, appears in fact to be an equation of the change in the output gap. To see this, note that the coefficient on contemporaneous potential output is unity and highly significant. Furthermore, the coefficients on the lagged change in real and potential output is approximately equal with opposite signs. Rewriting this equation in terms of the change in the output gap yields

$$\Delta(y^r - y^{rn})_t = 0.91\Delta(y^r - y^{rn})_{t-1} + \dots$$

¹⁶A sensitivity analysis was performed by keeping ecm_{t-1}^{ir} in the system, but it did not enter significantly in any of the equations.

The short-run system										
Equ. No.	1	2	3	4	5	6	7	8	9	10
	$\Delta^2 p_t^c$	Δy_t^r	Δm_t^r	Δi_t^s	Δw_t^r	Δa_t	Δu_t	$\Delta \tau_t^w$	$\Delta \pi_t^f$	Δi_t^l
Δy_{t-1}^r	—	0.91 (29.1)	—	-0.05 (-2.85)	—	—	-0.14 (-9.59)	9.55 (2.95)	—	—
Δi_{t-1}^s	—	—	—	0.41 (6.35)	—	—	—	—	0.56 (3.89)	—
Δw_{t-1}^r	—	-0.32 (-3.92)	—	—	-0.37 (-4.50)	-0.37 (-3.99)	-0.02 (-2.13)	2.98 (2.35)	—	-0.02 (-2.47)
Δa_{t-1}	—	-0.72 (-26.1)	—	—	-0.18 (-2.22)	—	0.10 (7.56)	-6.91 (-2.19)	—	—
Δu_{t-1}	—	—	—	—	2.21 (2.39)	—	—	73.28 (5.07)	—	—
$\Delta \pi_{t-1}^f$	—	-0.06 (-3.19)	—	—	-0.27 (-2.33)	—	—	—	0.59 (11.2)	—
Δi_{t-1}^l	0.81 (3.30)	—	4.55 (2.68)	—	—	—	-0.18 (-3.17)	—	1.29 (4.19)	0.28 (4.26)
Δy_t^{rn}	-0.04 (-3.23)	1.00 (145)	—	—	—	—	—	—	—	—
Δy_{t-1}^{rn}	—	-0.99 (21.0)	—	0.06 (3.08)	—	-0.10 (-2.54)	0.14 (8.83)	-7.38 (-2.19)	-0.08 (-5.53)	—
Δi_t^f	—	—	—	—	—	—	—	—	—	0.75 (7.92)
ecm_{t-1}^{is}	—	-0.73 (-4.45)	—	-0.08 (-2.86)	—	-0.70 (-3.69)	0.04 (2.54)	-5.95 (-2.27)	—	—
ecm_{t-1}^{pc}	-0.74 (-9.06)	—	—	—	—	—	—	—	-0.50 (-4.77)	—
ecm_{t-1}^{pmu}	—	-0.99 (-5.42)	-1.10 (-2.64)	—	—	-1.14 (-5.36)	—	—	—	—
ecm_{t-1}^{wc}	—	—	—	—	-0.07 (-2.84)	—	—	-1.62 (9.48)	—	—
ecm_{t-1}^{ur}	—	—	—	—	0.14 (3.38)	—	—	—	—	—
ecm_{t-1}^{uip}	—	—	-2.35 (-3.00)	—	-1.29 (-3.86)	—	—	—	-0.79 (5.90)	-0.11 (4.01)
$D89$	—	—	—	0.008 (7.97)	—	—	—	—	—	—
$D91$	—	—	—	-0.006 (-5.63)	—	—	—	—	—	-0.00 (2.61)
$D92$	—	—	—	-0.006 (-6.12)	—	—	—	-0.52 (-6.25)	—	—
$D92b$	—	—	—	-0.009 (-6.35)	—	—	—	-0.36 (-2.97)	—	-0.00 (-2.80)
μ	0.00 (0.23)	0.01 (7.99)	0.01 (4.76)	-0.00 (-0.84)	0.01 (5.94)	0.01 (9.82)	-0.00 (-0.15)	-0.00 (-1.83)	-0.00 (1.76)	0.00 (0.34)

Table 12: The short-run system. The centered seasonals are not reported in the table to save space.

The lagged change in the output gap also enters the equations of the change in interest rates, the change in unemployment, and the change in the payroll tax.

6.1 Explaining Finnish inflation

Equation 1 explains the change in Finnish quarterly inflation. Writing out this equation in full yields

$$\begin{aligned} \Delta^2 \hat{p}_t^c = & \underset{(3.30)}{0.81} \Delta i_{t-1}^l - \underset{(-3.23)}{0.04} \Delta y_t^{rn} \\ & - \underset{(9.06)}{0.74} (\Delta p^c - \underset{(-3.80)}{0.04} (y^r - y^{rn}) + \underset{(8.57)}{0.001} t)_{t-1} \end{aligned} \quad (25)$$

It is clear from the equation, that the only long-run explanation of (the change in) inflation is the Phillips curve, ecm_{t-1}^{pc} , relating excess demand positively to inflation. The results in Juselius (2006) suggests that this Phillips curve is *not* of the forward looking new Keynesian type, and can thus be interpreted as a more traditional Phillips curve. This results is in accordance with a point made by Rudd and Whelan (2005), page 13, that

“...neither [the difficulties of measuring potential output] nor the failure of the new-Keynesian Phillips curve when a traditional output gap measure is used should, on their own, be taken as reasons to discount the usefulness of standard gap measures as indicators of inflatory pressures.”

The significant time trend in ecm_{t-1}^{pc} is, as mentioned in section 5.1, not entirely satisfactory. It implies that some long-run stochastic trend in inflation is yet unaccounted for. Two variables come close to approximating this trend. The first is labor’s share and the second is the long-term interest rates series (see ecm_{t-1}^{pmu} and ecm_{t-1}^{ir}). However, as is apparent from table 12, neither of these provide good explanations of inflation and in this respect, some part of the inflation process is left unexplained.

In the short-run, the change in inflation is positively affected by the previous period change in the long-term interest rates, and negatively by a current period change in potential output. The positive effect from the interest rate is similar to that which was found in ecm_{t-1}^{ir} , and implies some co-movement of inflation and the long-term interest rate. The negative effect from a change in

current potential output is natural, since it lowers the pressures from excess demand.

Thus, the general picture suggests that Finnish consumer inflation, is mainly determined by excess demand pressures and changes in the long-term interest rates. Other sources of inflatory pressures are indirect, stemming from the determinants of the output gap and the long-term interest rate (equations 2 and 10 in table 12).

It is instructive to compare the system estimate of the inflation process with a single equation estimate. If Finnish consumer inflation is estimated in a single equation, using the same information as above, the resulting parsimonious specification is given by

$$\begin{aligned}
\Delta \hat{p}_t = & \underset{(2.55)}{0.001} - \underset{(-2.71)}{0.04} \Delta m_{t-1}^r - \underset{(-2.37)}{0.004} \Delta \tau_{t-1}^w + \underset{(3.53)}{0.97} \Delta i_{t-1}^l \\
& - \underset{(-3.30)}{0.05} \Delta y_t^{rn} - \underset{(3.28)}{0.14} \Delta \pi_{t-1}^d - \underset{(-4.80)}{0.59} ecm_{t-1}^{pc} \\
& - \underset{(-2.00)}{0.19} ecm_{t-1}^{pmu} .
\end{aligned} \tag{26}$$

There are no significant misspecification in this equation and the adjusted R^2 is 0.78. Note that there are more factors explaining inflation in equation (26) than in the corresponding system estimate. Thus, it appears that single equation estimates find more determinants than is warranted. Moreover, the estimate in (26) uses the system derived knowledge on the weakly exogenous variables. However, if such information is lacking, as in Hendry (2001), the problem will be even worse.

6.2 The rest of the system

Table 12 also reveals some interesting dynamics with respect to the other endogenous variables. Equation 2 in the table describes the change in the output gap (given the interpretation in the beginning of this section). Two long-run relations enter significantly into the equation, ecm^{is} and ecm^{pmu} . Only the first of these, ecm^{is} , contain real output and is error correcting. The relationship is broadly consistent with an IS curve, i.e. higher real interest rates are associated with a lower real level of output. The other relation, ecm^{pmu} , is more difficult to interpret since neither real nor potential output enters in it. In the short-run, the change in the output gap is affected negatively by changes in real wages, and the price differential between domestic

and foreign prices. Both of these effects seem natural. The change in the output gap is also negatively related to the change in labor productivity which is counter intuitive.

Equation 3 describes the change in real money, but is neither very successful in explaining this variable nor terribly interesting. Equation 4 on the other hand describes the change in short-term interest rates. The only long-run determinant is the IS curve, ecm^{is} , which is a natural result. Thus, real output and the short-term interest rate are determined together along an IS curve. In the short-run, the change in the short-term interest rates is negatively affected by a change in the output gap.

Equation 5 describes the change in wages. In the long-run, wages are determined by the wage curve, ecm^{wc} , the unemployment relation ecm^{ur} , and the UIP condition, ecm^{uip} . Only the wage curve is error correcting in the equation, since it contains real wages and enters with a negative sign. The unit coefficient on a^l in ecm^{wc} suggest that real wages completely incorporate changes in labor productivity in the long-run. In addition, wages are negatively affected by a change unemployment¹⁷. The other long-run relations are more difficult to interpret since they are not error correcting, but include effects from the unemployment relation and the UIP condition.

Equation 6 describes the change in labor productivity, which is determined in the long-run by ecm^{pmu} and ecm^{is} . Only ecm^{pmu} is error correcting in the equation. Interestingly, since ecm^{pmu} was not error correcting in the inflation equation, it is labor productivity and *not inflation* that is adjusting to ensure constant mark-ups. This adjustment probably takes place as firms lay off the least productive workers when marginal costs are perceived as high. This impression is strengthened by the short-run effects. In the short-run, changes in real wages and potential output lowers labor productivity. This is offset in the long-run by the effects from ecm^{pmu} .

Equation 7 describes the change in the unemployment rate. However, since neither ecm^{wc} nor ecm^{ur} are significant in this equation, there are no long-run error correction mechanisms. Thus, the unemployment equation 7 is somewhat unsatisfactory.

Equations 8 and 9 describe the changes in τ_t^w and π_t^f , respectively. Neither of these are interesting, and are not discussed here. Finally, equation 10

¹⁷The large coefficient on unemployment in ecm^{wc} is probably due to the dramatic changes in unemployment over the sample period. Its effect on wages is partially offset by the positive effect from ecm^{ur} .

describes the change in the long-term interest rate. As can be seen from the equation, the only long-run determinant is the approximate UIP condition. The equation implies that the long-term interest rate changes to ensure that this condition holds. Thus, the UIP condition indirectly affects inflation through its effects on the long-term interest rate.

6.3 Comparing the results to previous studies

It is instructive to compare the results of this paper to those obtained in the previous inflation studies by Juselius, K. (1992), Metin (1995), and Hendry (2001).

Juselius, K. (1992) analysed inflation using quarterly Danish data over the sample 1974:1-1987:3. She derived long-run feedback relations describing excess demand for money, wage formation, and deviations from both the PPP and the UIP. She also found a fairly similar mark-up pricing relation to that found in this paper, but did not include it in the model of inflation. Her results suggested that the main determinants of Danish inflation were disequilibria in the international parity conditions and excess money demand, while wage formation played a smaller role. Her estimate of the Danish inflation process was obtained as a single equation, and may therefore overstate the importance of some of the determinants.

Metin (1995), analysed Turkish annual data over the relatively short sample of 1950-1986. He derived feedback relations describing, money demand, an IS curve, debt-inflation, and deviations from PPP. He found that Turkish inflation is primarily determined by government debt formation. It is difficult to compare the results of this paper to those of Metin, due to the different economic histories of Finland and Turkey and to the focus on government debt.

Finally, Hendry (2001), analysed UK inflation on annual data over the period 1865-1991. He used theory derived empirical feedback relations of, excess demand of goods and services, excess money demand, interest rates and debt, real exchange rates, mark-up pricing over labor costs, and excessive labor demand. He found that mark-up pricing, the interest rate differential and excess demand of goods and services are the most important determinants of UK inflation. He concluded that there is no single-cause explanation of inflation.

Overall, the evidence is mixed and the inflation experience is different in different countries, with no single factor being particularly important.

However, it should be stressed that the studies differ extensively in sample periods, and to some extent, in methods.

7 Conclusion

This paper estimated the relative importance of different inflation theories on the Finnish inflation process. The data consisted of quarterly observations on a large number of variables over the period 1982:1-2006:1. Due to the large information set needed to evaluate the different inflation theories, an approach originally suggested by Surrey (1989) and Juselius, K. (1992) was adopted. By this approach the general information set was divided into smaller subsets, each corresponding to a particular theory. Long-run feedback relations were obtained from each subsystem and then combined to estimate a complete system. The theories were evaluated based on the statistical relevance of their corresponding feedback relations in the Finnish inflation process.

The cointegrated VAR model for $I(2)$ data was used to obtain the data consistent feedback relations. This model allows for testing nominal to real transformations which are commonly assumed to hold. The complete system was estimated using FIML.

Several interesting results emerged. The evidence suggest that main determinant of Finnish inflation is excess demand in the goods markets. Other explanations such as mark-up pricing, monetarist theories, or inflation pass-through have comparatively little to contribute. There is also evidence of an IS relationship in the data, that simultaneously determines real output and the short-term interest rate. Long-term interest rates are determined by adjustments to an approximate UIP condition in the long-run

The use of the $I(2)$ model produced some interesting results, as well. The evidence suggested that the nominal variables are integrated of order two. However, nominal to real transformations are valid in most cases, suggesting that nominal Finnish $I(2)$ data usually can be converted into real $I(1)$ data without serious loss of information.

A Data

This appendix presents the precise definitions and sources for the data used in the analysis. The sample of quarterly data is 1982:1-2006:1. Two main sources have been used in collecting the data. The OECD data-bases (economic outlook and main economic indicators) and the ETLA (Elinkeinoelämän Tutkimuslaitos) data-bases. The series were

p_t^c is the (log of) consumer price index with base year 2000. OECD economic outlook.

p_t^p is the (log of) producer price index with base year 2000. OECD economic outlook.

p_t^y is the (log of) GDP deflator with base year 2000. OECD economic outlook.

p_t^f is the (log of) trade weighted foreign consumer price indexes. OECD economic outlook.

m_t is the (log of) Finnish M3. ETLA.

y_t is the (log of) nominal GDP, ETLA.

y_t^n is $y_t + r_t$, where r_t is the (log of) ratio of potential output to actual. The potential output series is constructed by the production function method (see Giorno et al., 1995). OECD economic outlook.

i_t^s is a 3-month interest rate series. OECD economic outlook.

i_t^l is the yield on 10-year government bonds. OECD economic outlook.

i_t^f is European long-term interest rates. OECD economic outlook.

w_t is (the log of) an earnings index of all sectors of the economy. ETLA.

q_t is (the log of) a measure of labor productivity in the business sector. OECD main economic indicators.

u_t is the unemployment rate. OECD economic outlook.

e_t is the (log of) nominal effective exchange rate. OECD economic outlook.

τ^w is the (log of) the ratio of wage taxes to wages and salaries. ETLA.

τ^c is the (log of) the ratio of indirect taxes to consumption. ETLA.

The analysis also made use of four dummy variables. These are defined as

$$\begin{aligned}
 D89 &= \begin{cases} 1 \text{ for } 1989:4 \\ -1 \text{ for } 1989:4 \end{cases} \\
 D91 &= \begin{cases} 1 \text{ for } 1991:2 \\ -1 \text{ for } 1991:4 \end{cases} \\
 D92a &= \begin{cases} 1 \text{ for } 1992:1 \\ -1 \text{ for } 1992:2 \end{cases} \\
 D92b &= 1 \text{ for } 1992:4
 \end{aligned}$$

The first three dummies correspond to various speculative attacks on the FIM, due to the adopted policy of “the strong markka”, Honkapohja and Koskela (1999). $D92b$ corresponds to a level shift in the interest rates due to the floating of the FIM.

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